The Bloch sphere

Read a geometric picture without mistaking it for the physical device.

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By the end, you'll be able to

- Convert qubit angles into Bloch coordinates.
- Explain the pure-state limitation of the explorer.

Coordinates for a pure qubit

For the angle representation in F07, the Bloch coordinates are

$$x = \sin\theta\cos\phi, \qquad y = \sin\theta\sin\phi, \qquad z = \cos\theta.$$

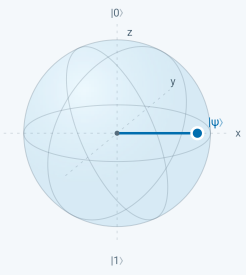
They satisfy $x^2 + y^2 + z^2 = 1$. In terms of amplitudes, $x = 2\,\mathrm{Re}(\alpha^*\beta)$, $y = 2\,\mathrm{Im}(\alpha^*\beta)$ and $z = |\alpha|^2 - |\beta|^2$. The north pole is $|0\rangle$, south is $|1\rangle$, positive x is $|+\rangle$, and positive y is $(|0\rangle + i|1\rangle)/\sqrt{2}$.

L01 · INTERACTIVE LAB

Runs on your device

Qubit explorer

A pure qubit is a normalised pair of complex amplitudes. The sphere shows the state; the bars show measurement probabilities in the Z basis.



Exact probability

|0⟩ 50.0%

|1⟩ 50.0%

MODEL · Ideal pure-state vector, complex double precision ORDER · q0 is the leftmost bit

Prediction: Move the state to the equator. What will happen to the Z-basis probabilities when you change only the phase? Challenge: Create a state with a 75% probability of measuring 1. Can you find two different phases with the same probabilities? Open the live experiment studio.

A worked point

At $\theta = 90^\circ$ and $\phi = 90^\circ$, the coordinates are $(0, 1, 0)$. The Z probabilities are $P(0) = (1 + z)/2 = 1/2$ and $P(1) = (1 - z)/2 = 1/2$.

Move ϕ around the equator. The arrow direction changes while z stays zero. This makes it easy to see why a single Z measurement setting misses relative phase.

What lies inside?

Mixed single-qubit states have Bloch vectors of length at most one. The maximally mixed state sits at the centre. It is different from an equatorial pure state even though both can have equal Z probabilities. Describing mixed states properly requires density matrices, planned in X01.

This explorer deliberately models pure states only. The projected ellipse and arrow are drawing choices; they do not depict a hardware qubit's literal shape.

Check yourself: identify the coordinates of $|-\rangle$. They are $(-1, 0, 0)$.

Reference: Microsoft Learn — The qubit.