Table 1: *Classical* system play results (actual)

Setup		Guess	Verify		Score
$\Downarrow X$	$\Downarrow P$	$(X$ **and** $P)$	$\Downarrow X$	$\Downarrow P$	
b	d	(b, d)	b	d	$+\$1$
b	s	(b, s)	b	s	$+\$1$
b	s	(b, s)	b	s	$+\$1$
r	d	(r, d)	r	d	$+\$1$
r	s	(r, s)	r	s	$+\$1$

Table 2: *Quantum* system play results (actual)

Setup		Guess	Verify		Score
$\Downarrow X$	$\Downarrow P$	$(X$ **and** $P)$	$\Downarrow X$	$\Downarrow P$	
b	d	(b, d)	b	s	$-\$2$
b	d	(b, s)	r	s	$-\$2$
b	s	(b, s)	b	s	$+\$1$
r	s	(r, d)	b	s	$-\$2$
r	s	(r, s)	r	s	$+\$1$

At the end of this particular game the C is up \$1, which seems good to C especially since he has the classical half of the game down pat. Before continuing with another game, the Classical Scientist would be wise to not be beguiled and should consider the following, **the Quantum house always wins!** Using classical reasoning with quantum systems is a losing proposition[2].

[2]Hint: **Quantum measurement prepares the system** into a particular state. Component measurements are not necessarily simultaneously compatible, thereby randomizing the results of successive measurements.

An Impressionist Quantum Primer

§Introduction

> Quantum weirdness is a resource, not a nuisance.
> — TC Burt

(Caution: Brief descriptions of quantum mechanics, even with mathematics, carry the easily-realized potential to be wrong. Don't carry the qualitative narrative too deeply.)

§§Quantum Resources

Measurement changes things
Superposition increases things

Entanglement intertwingles thingles Wonderful, mysterious, and treacherous.

§§Quantum Information Processing Triad

Sensing refined measurement, novel imaging
Communication provable (or at least enhanced) security, protected information exchange, detectable adversaries, key generation and distribution
Computing exponentially faster calculations, tractable simulation of physical systems

§So They Say

> Quantum theory provides us with a striking illustration of the fact that we can fully understand a connection though we can only speak of it in images and parables. — Werner Heisenberg in *Physics and Beyond : Encounters and Conversation*

> These references to Born [...] are meant to illustrate the difficulty of putting aside preconceptions and listening to what is actually being said. — John S. Bell in *Bertlmann's Socks and the Nature of Reality*

> I don't like it, and I'm sorry I ever had anything to do with it. — Erwin Schrödinger, one of quantum physic's founding scientists (attributed by John Gribbin, *In Search of Schrödinger's Cat*)

> Do you guys just put the word quantum in front of everything? — Scott Lang in the movie *Ant-Man and the Wasp*

§Beguiling Headlines

headline popular understanding ⇒ *corrective comment*

it's both at the same time the cat is not just alive or dead, but both at the same time ⇒ *it is a* superposition *of "both" states but can also be a superpostion of "other" states as well*

spooky action at a distance manipulation of one part of an entangled system influences the other part instantaneously no matter how distant they are from each other ⇒ *they are a single system, one part does not* act *on the other, and information transfer obeys the cosmic speed limit*

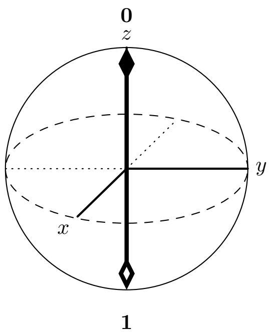
delayed choice quantum eraser *after* measuring part A of a system a choice is made in part B that effects whether particle or wave observations appear in the first part ⇒ *one part does not act on the other (oh, we already said that) . . . recognize that classical communication between the parts is necessary and that post-selection based on coincidence measurements reveals the particle or wave nature (but the original entanglement itself is still weird!)*

teleportation

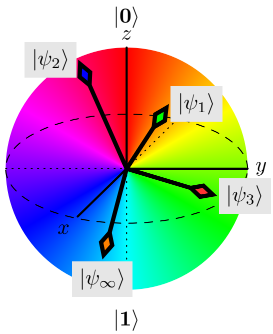
many-worlds theory implies an ever-burgeoning number of universes exist to accommodate all possible outcomes, including a universe where we do not continue to pursue quantum technology ⇒ *that just can't be right*

§Bits and Qubits

Bits give you two extremes



Qubits give you the world



§Weird and Wonderful Stories

§§Bell's Bar Bet

A classical statistician and a quantum physicist walk into a bar[1]. They play a game recording only joint observations between systems, then calculating a particular sum of the values. Both are well versed in classical probability theory, their observations are flawless, and they play fair. They take turns choosing systems from around the tavern and the calculation always yields 2 or less, which comes as no surprise to either of them.

Now comes the hustle. The physicist pulls two *entangled systems* from her pocket and bets the other a drink that this round of the game will yield a value greater than 2. The statistician salivates for the Seagram's coming from this sucker bet. They play the game and obtain the value 2.5. The physicist figures something must have jumbled in her pocket because she expected about 2.8. She shrugs and orders a tea; physicists like tea.

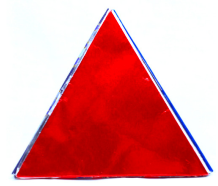
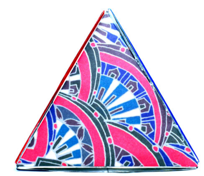
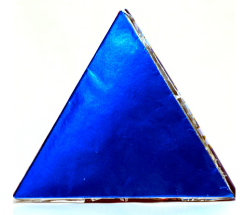
§§Better Tales

- In Search of Schrödinger's Cat by John Gribbin
- Feynman Lectures on Computation by Richard P. Feynman (edited by Tony Hey and Robin W. Allen)
- The Quantum World by J.C. Polkinghorne
- Mr. Tompkins in Paperback by George Gamow
- Alice in Quantumland by Robert Gilmore
- Quantum Computing Since Democritus by Scott Aaronson

§One Game, Two Logics

Consider a system that is described by the value of two different components: Xolor (pronounced color) and Pattern. Each component has two values when measured: red/blue for Xolor and solid/design for Pattern. A four-sided die (tetrahedron) can represent each pair of component values on its faces for a classical game (see following table).

[1]"You'd have thought the second one would have noticed." — Steven Wright

Xolor (X)	**Pattern** (P)	
	solid (s)	design (d)
red (r)		
blue (b)		

There are two players, the Classical (C) and Quantum Scientist (Q). Both are honest and both have a firm grasp of classical reasoning. The only difference is that C does not know quantum mechanical reasoning whereas Q does. Game play for a single round proceeds in four stages: Setup, Guess, Verify, and Score.

1. Setup: Q *prepares* the system and honestly records the results of *measuring* the components in succession, X then P. Note: Measuring with the tetrahedron described previously means observing the face of the die that is down, and *only for that component being measured at the moment*; any other presumed information is not regarded.
2. Guess: C guesses the state of the system by recording the values that X and P hold simultaneously at this stage of play.
3. Verify: Q *measures* the components of the system again in succession, X then P.
4. Score: Together C and Q compare the verified values to the guessed values. If the results of X **and** P match then C gains $1. If the results do not *both* match then C losses $2.

The Scientists agree to play ten rounds, five with a classical system and five with a quantum system.