Quantum Weirdness

Weirdness = Does Not Agree with my Prejudices.

Prejudices = Classical Physics.

Quantum Mechanics Is Not Classical Physics In Disguise.
Probabilities

Pascal - Betting

Maxwell, Boltzmann.

Probabilities in Physics.

Lack of Knowledge.

Probability Green Particle being in certain region without sufficient reason, Particle has equal Prob anywhere.
But Particle Reality is at some definite place.

Probability is due to our handling, lack of knowledge of true state of world.
Refinement of Sorting
There exists some property of Silver atom that this is sorte for.

Second Sorter

Another attribute?

Sort Same attribute

Sort Diff atribui
Refinement of Sort?

No.

- Output At End Is 50-50 Again.

Fundamental Probabilities
Explanation (?) (Heisenberg, 1925)

- The measurement of the second attribute alters the first.

\[ \text{Rotates around } B \]

The measurement of one attribute alters the "conjugate" attribute.
Can we make a classical model of Q. Mech.? (Use "measurement effect")

J. S. Bell (believed strongly answer "Yes")

(Proved Answer "No")

Attribute ↑

If particle with attribute ↑ goes through sorting machine ↓ - sorted up always.

↓ sorted down.
Prob. up = \( (\cos \frac{\theta}{2})^2 \)

(Toward N)

Probabilities Inherent
(Are they due to lack of knowledge?)
MAKE A 2-PARTICLE STATE.

Sorting into same direction bins perfectly correlated.

Run 4 experiments sorting into bins combinations.
As long as measurements on blue cannot affect outcomes on maroon.

\[ \text{Up-Down A} = \langle A \rangle \]

\[ \langle AC \rangle = \frac{\# \text{ Same} - \# \text{ Diff.}}{\# \text{ Tot.}} \]

\[ |\langle AC \rangle + \langle AD \rangle + \langle BC \rangle - \langle BD \rangle| \leq 2 \]

(Classical).

But

\[ = 2\sqrt{2} \approx 2.8 \]

Quantum & experiment.
Cannot explain quantum by measurement effect. (Heisenberg wrong)
Cryptography.

Alice and Bob randomly choose ↑ or ↔ to measure.

a) (If choose same, know results anticorrelated.)

b) Phone (don't care if Eve hears) + pick out those cases where same direction
(If Eve did not interfere must have opposite results)

(c) Compare results of small subset. If not opposite - Eve listened in. \( \Rightarrow \) Discard all.
Hardy State:

\[ L_1 \quad R_1 \]
\[ L_2 \quad R_2 \]
\[ \oplus \quad \ominus \]

(a) If \( L_1 + R_1 \) measured and \( L_1 = + \), then always \( R_1 = + \)

(b) If \( R_1 + L_2 \) meas. and \( R_1 = + \), then \( L_2 = + \)

(c) If \( L_2 + R_2 \) meas and \( L_2 = + \), then \( R_2 = + \)

(d) If \( L_1 \) and \( R_2 \) meas. and \( L_1 = + \), what is \( R_2 \)?


\[ L_1 = + \implies R_1 = + \]
\[ R_1 = + \implies L_2 = + \]
\[ L_2 = + \implies R_2 = + \]

\[ L_3 = + \implies R_3 \text{ almost always is } - \]

**Transitivity of classical argument is false.**
Initial, Final Conditions

In classical physics, all conditions are the same as initial conditions.

\[ \uparrow \]

All conditions are the same as initial conditions.
Attribute Spin = 12.5
(i.e. Values of spin in any direction)
-12.5, -11.5, ..., 10.5, 11.5, 12.5


Interact with spin in certain direction
Needle displaced amount prop. to spin measured
1) Measure accurately spin in x direction. Keep only those with Spin 14

2) Measure poorly spin in 45° direction

3) Measure spin in y direction & keep only cases where spin 14

What is spin in 45° direction?
(a) Measure accurately

Measure Poorly

Future Past interfere to give "impossible" value intermediate times.
Bomb Detector

1 photon

1 photon sets off bomb.

Can you test if bomb is good or not?

without blowing up the good bomb?
polarized light.

rotated by $\epsilon$

If beams recombine
No Rotn.

Prob. of explosion $\epsilon^2$

If good bomb
No return beam
Rotn by $\epsilon$
Rotation

\[ N \epsilon = \frac{\pi}{2} \]

Prob. of explosion

\[ = N \epsilon^2 = \frac{\pi \epsilon^2}{4N} \]

If \( N \) large - prob of explosion very small if good bomb.

But rotu of polsu of beam is 90°

If bomb bad, rotu is 0°. - Can measure exactly.
Quantum Mechanics can detect Good Bomb without exploding it.

Procedure relies completely on fact bomb would explode with single photon!