How to prove if quantum theory is correct?

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Abstract:
We have proposed an envelope experiment to illustrate the spin orientation of electrons. Then we deduced an inequality and showed that quantum computer can violate it.

1 Introduction

The motivation is that quantum mechanics predicts perfect correlations between spin measurements of harmonized electrons. Einstein, Podolsky and Rosen called this a “spooky action at a distance,” and argued that quantum mechanics was incomplete, because the speed of information between two electrons has to be faster than speed of light. Then Bell came and showed that in situations which Einstein, Podolsky and Rosen had in mind the correlations must satisfy certain inequalities.

2 Correlations in an envelope experiment

2.1 Proposal

Let there be an envelope containing two medium envelopes (electrons) which each contain three marked small envelopes. Each of them carrying binary information (the spin),

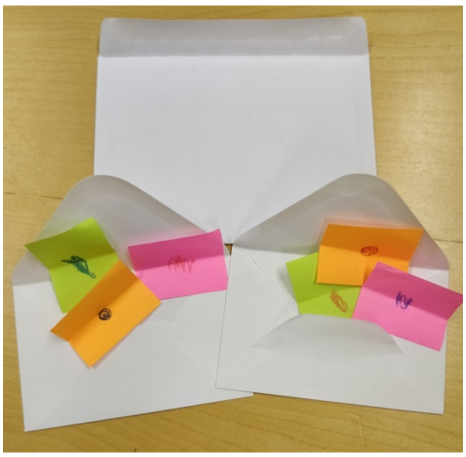

Figure 1 The envelopes

represented by either red or blue dot. The spin information will always be negative of the information in the respective small envelope.

First, we distribute the medium envelopes to two different people (Alice and Bob) and they each open their medium envelope and randomly choose one of the small envelopes.

2.2 Probabilities

Based on the rules by which the small envelopes are created, we can divide them into four groups.

Group	First envelope	Second envelope	Probability
A	r r r	b b b	W_a
B	r r b	b b r	W_b
C	r b r	b r b	W_c
D	r b b	b r r	W_d

P(1r,2r) represents the probability of Alice opening the first small envelope and finding red dot, and Bob opening the second small envelope and finding red dot. Mathematically, we can express all of these probabilities by sums of probabilities of the group that fulfil the criteria.

2.3 Bell's inequality

An example of a Bell's inequality is

$$p(1r, 2r) + p(2r, 3r) - p(1r, 3r) \geq 0 \tag{1}$$

This can be changed by substituting $p(1r, 2r) = \frac{1}{18}(W_c + W_D)$, $p(2r, 3r) = \frac{1}{18}(W_B + W_C)$, $p(1r, 3r) = \frac{1}{18}(W_B + W_D)$ into $\frac{1}{18}((W_c + W_D) + (W_B + W_C) - (W_B + W_D)) \geq 0$.

And this simplifies into

$$2W_c \geq 0.$$

3 Correlations in a quantum computer

The electron spin can be simulated by qubit in a quantum computer

3.1 The interface to the IBM Q

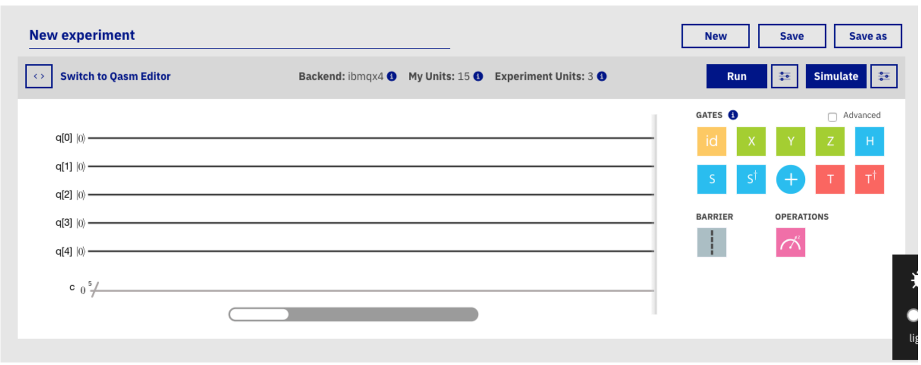

Figure 2 The web interface of IBM Q

Each qubit is represented by a line and we can drag gates onto these lines to create a quantum algorithm. We can run or simulate the algorithm by clicking in the appropriate button.

3.2 Bell's state

The Bell's state on figure 3 is such a state that the two qubits are perfectly anti-correlated, that means if one qubit is found to be 0 then the other is sure to be 1. This is the state used in the EPR paradox.

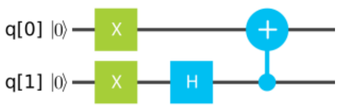

Figure 3 The code for a Bell's state

3.3 Rotations

The EPR experiment requires to rotate the spin detectors. This can't be achieved in IBM Q, so the qubit itself is rotated. We use the H gate to rotate about the x axis by 90°, and the T gate to rotate about z axis by 45°.

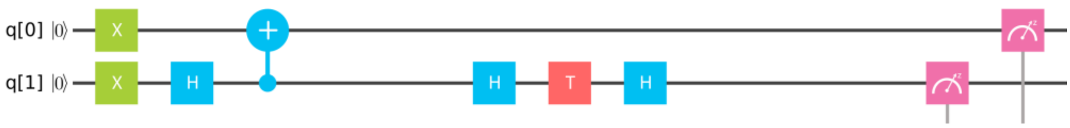

Figure 4 **p(1,2)**

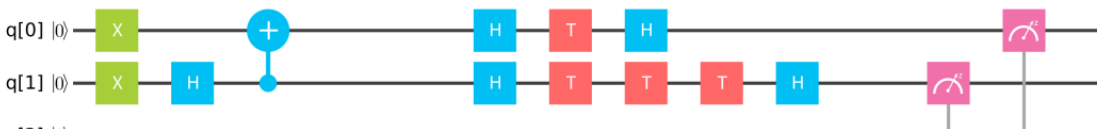

Figure 5 **p(2,3)**

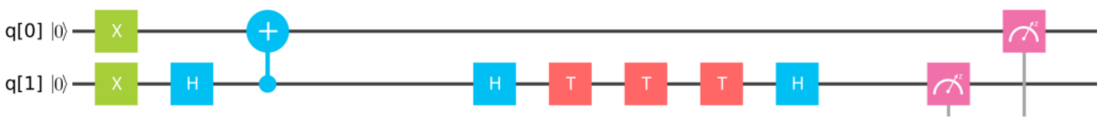

Figure 6 **p(1,3)**

Setting #1 corresponds to the z axis, setting #2 is rotated by 45° about the y, setting #3 is rotated by 135°.

3.4 Results and violation

The results given by the quantum computer are shown in figures 7-9.

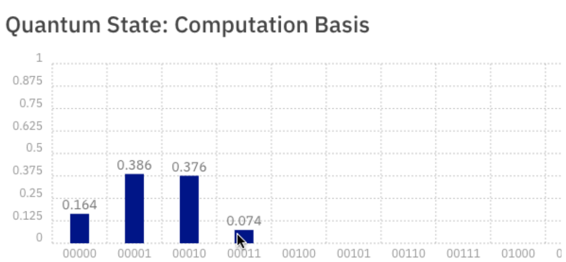

Figure 7 results for the algorithm on figure 4

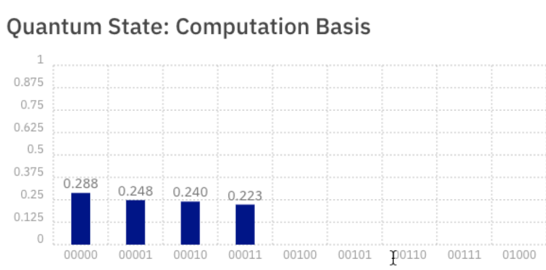

Figure 8 results for the algorithm on figure 5

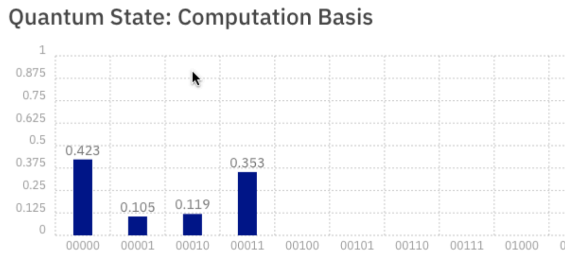

Figure 9 results for the algorithm on figure 6

If we associate zeros with blue and red with ones, we can read off the values p(1r,2r), p(2r,3r) and p(1r,3r). We substitute this into inequality (1) and the result is

$$0.74 + 0.223 - 0.353 = -0.056 \geq 0,$$

what is contradiction.

4 Conclusions

We have executed the proposed experiment and deduced the probabilities then we proceeded with experiment IBM Q and shown that the Bell’s inequality is violated. This experiment proves that quantum mechanics can violate Bell’s inequality. To prove that quantum mechanics is correct we would need to do this experiment with the two qubits at great distance.

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