Spooky Action at a Distance or Not

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Synopsis:

An Alternative Interpretation of Bell's Theorem Experiments

A misinterpretation of the results of the Stern-Gerlach experiment in conjunction with Bell's theorem has led much of the physics community to make an erroneous assumption that, in turn, has resulted in acceptance of non-local behavior of entangled pairs. That is to say: something moving faster than the speed of light.

This paper describes Bell's Inequality. It goes on to describe the failure of Bell's Inequality in experiments. These experiments are often referred to as Bell's Theorem. The paper goes on to describe the assumption made and how that assumption results in a misapplication of Bell's Inequality. Further, the paper shows how the application of classical physics will produce results that agree with the results found in those experiments.

The paper is written for the general public. As such, the use of mathematics is kept to a bare minimum and uses constructs understandable at a high school level.

Many physicists are uncomfortable with the non-local (faster than light) conclusion of the failure of Bell's Inequality experiments. Some point to hidden variables to explain the results. Others point to loopholes in the calculations. Still others suggest the wrong mathematical model was used in evaluating the results.

The following will show that neither Bell's Inequality nor the calculations associated with experiments are in error. Instead, an assumption is inherent in the evaluation that leads us to the wrong conclusion. Moreover, that assumption can trace its roots to experiments run as long ago as 1922.

Bell's Theorem:

Bell's Inequality tests the correlation between two detectors when measuring parameters of random entangled pairs during which the detectors are randomly oriented in one of three directions.

To clarify, we will describe an experiment. We start with a source of entangled particles. When particles are created, they are generated in pairs. Some characteristics are identical and others are opposite. For example, an electron and positron pair will have equal mass but opposite charge and opposite spin. In this experiment, the source of entangled particles sends each member of the pair in opposite directions.

At an equal distance in each direction from the source of particles we place a spin detector. Each of the two spin detectors may be placed in one of three orientations: 1) opposite each other, 2) 120 degrees before being opposite the other, or 3) 120 degrees after being opposite the other. During the experiment, the spin detectors will be randomly placed in each of these orientations. Each spin detector will register a particle as either spin “Up” or spin “Down”.

Detector Orientations

Before we start the experiment, we check the apparatus with both detectors in random orientations but with each detector always oriented opposite the other detector. We detect an equal number of “Up” and “Down” spin showing that the source is random. We also find that throughout this test both detectors read the same for both particles of each pair. That verifies that the particles are truly entangled.

Now we run the experiment with each detector randomly oriented in any of the three directions. Let us first predict what we can expect.

Particles are generated with spin in any direction. Our detector can only sense the spin portion of spin perpendicular to the direction of travel. The detector will read Up (spin up) if the direction of spin is at all in the up direction and Dn (spin down) if the spin is at all in the down direction.

The directions of the sensors are truly random. That is to say that statistically each orientation combination can be expected the same number of times. The directions of the generated spins are also truly random (though the entanglement relationship of opposite spin in each pair is always true).

We can now construct a table of all possible directions of particle spin and all possible detector orientations. The left hand column represents the range of spin direction that the particles going toward the Left sensor exhibit. Since the spin directions are random and each of these ranges are identical (60 degrees), it is reasonable to say that approximately the same number of electron pairs will be represented by each row. This becomes truer as we increase the number of samples taken

Columns 2 through 7 represent the result of detection for the left (L) and right (R) sensors in each of the orientations, 1, 2, or 3. We can also surmise that each of the detection table entries occur approximately the same number of times because the orientations are random. That becomes truer as we increase the number of samples taken.

The right 9 columns represent the correlation between different sensor orientations. For example, the first row under 1-1 says that L1 and R1 are the same (S) and the first row under 1-2 says that L1 and R2 are different (D). For a similar reason as given for the previous fields, each combination of sensors come into play approximately the same number of times. Again, the more samples, the more this is true.

Direction	L1	L2	L3	R1	R2	R3	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3
270-030	Up	Dn	Dn	Up	Dn	Dn	S	D	D	D	S	S	D	S	S
030-090	Up	Up	Dn	Up	Up	Dn	S	S	D	S	S	D	D	D	S
090-150	Dn	Up	Dn	Dn	Up	Dn	S	D	S	D	S	D	S	D	S
150-210	Dn	Up	Up	Dn	Up	Up	S	D	D	D	S	S	D	S	S
210-270	Dn	Dn	Up	Dn	Dn	Up	S	S	D	S	S	D	D	D	S
270-330	Up	Dn	Up	Up	Dn	Up	S	D	S	D	S	D	S	D	S

If we add up the number of Ss we find that out of the 54 possible combinations, we have a correlation on 30 combinations. 30/54 is 5/9. Bell's Inequality says that if we do such a test, we will always get a result of 5/9 or greater.

Had the detectors not been evenly spaced, we would have to weight the effect of each row to account for the distribution of spins no longer being the same for each row. If the detector orientations are not the same for left and right, the table may have to expand into as many as 12 rows for source direction ranges.

I have written a program to try out different combinations of orientations. If you have a PC, you are welcome to download the program and play with different combinations of orientation. You can download from:

http://home.comcast.net/~gdderman/Bell.htm

Pseudo-code:

By the way, if you don't like the table approach to Bell's Inequality, a more general approach can be had using the following algorithm.

Note: the pseudo-code is not in the download program. However, it has been tested and the results do agree with the download program. The pseudo-code is used for a sensibility test of the explanation given later in this paper

In the pseudo-code that follows, I use increments of spin direction of 1 degree. But you can use any increment as long as you make sure you cover the full 360 degrees of spin direction and sensor orientation. The pseudo-code is as follows:

```
total = 0
same = 0
                                // test for all orientations of detectors a & b
for orient_a = 0 to less than 360 degrees in 120 degree steps
    for orient_b = 0 to less than 360 degrees in 120 degree steps
                                // test for all angles of spin
        for angle = 0 to less than 360 degrees in 1 degree steps
            correlation = detector(angle + orient_a) * detector(angle + orient_b)
                                // the portion of particles actually tested by both detectors
            if correlation is greater than or equal to 0 then
                same = same + correlation
            total = total + absolute value of correlation
                                // total of both same and different
result = same / total;
```

where the detector function returns a 1 for angles between –90 and +90 degrees and returns –1 for all angles in the other hemisphere.

Several interesting facts came out of exercising the download program. It turns out that even if the spacing between orientations is not 120 degrees, the value of 5/9 remains valid as long as all three detectors are not in the same hemisphere (we assume the same relative orientation for left and right sensors).

Once all sensors are in the same hemisphere, as you continue to move a pair of sensors (Ln and Rn), the correlation climbs above 5/9 toward unity as Bell's Inequality predicts. It will continue to climb until the pair of sensors is moved to between the other two. Then that value remains unless you move the outermost pair of sensors to be even closer together.

On the other hand, if you rotate all of the detector orientations of either left or right detectors, the correlation factor will become less, crossing through 0.5 in a sinusoidal dance between 5/9 and 4/9 (detector orientations spaced as in the original figure).

This is all very interesting, but lets get back to the task at hand. The result having to be greater than or equal to 5/9 was a real eye opener to the physics community. The intuitive result of 0.5 seemed gone forever. We now think we know what is going to happen.

Unfortunately, our experiment fails. This has been tried time and again, not only with spin but also with polarization. In all cases, the correlation approaches 0.5. That is what we intuitively thought would happen in the first place. But now we have convinced ourselves that such a result would be impossible.

The way the physics community has dealt with this conundrum is to say that entangled pairs retain their entanglement instantaneously. In measuring the "Up" or "Down" of the first particle to pass through the detector, we change its spin orientation. Its entangled partner must also change its spin simultaneously to maintain the opposite direction. The particles are moving apart at near the speed of light (or in the case of photons, at the speed of light). There is no way for the information to get to the second particle unless that information moves faster than the speed of light. That is in conflict with our understanding of Relativity.

Relativity argument:

There are some who argue that this does not violate relativity since there is no way to use the information that has moved so quickly. I do not agree with that argument. Relativity states that there is no such thing as simultaneous unless two events are co-located. As to there being no way to use the information, if non-local behavior is real, I have no doubt that man will find a way to use it.

The Solution:

I first gained my understanding of Bell's Theorem from a paper by Gary Felder published on the web at

http://www4.ncsu.edu/unity/lockers/users/f/felder/public/kenny/papers/bell.html

I still consider it the best source for someone trying to understand what Bell's Theorem is all about.

Once I found that I agreed with Bell's Inequality, I proceeded to write the download program mentioned above. The intent was to not only show the expected results from Bell's Inequality, but to then calculate the results (hopefully 0.5) that would be derived when non-local behavior was taken into account.

I proceeded to simulate the spin of one of each pair of particles being rotated to line up with the detector and applied the same logic as I did to derive the result. The result was not even close.

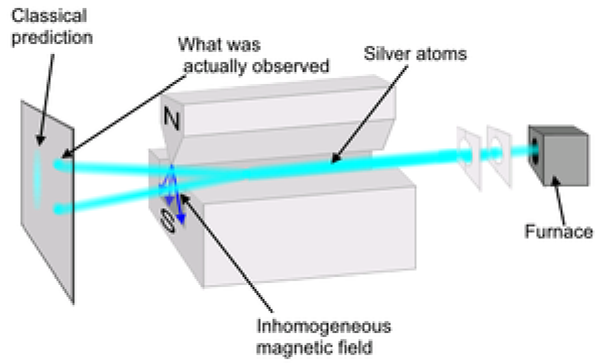
So I went back to the Felder paper and read it more carefully. Sure enough, he answered my question in Appendix III. He applied the probability expressions for the rotated spin that involved a cos squared function. Made sense. I was familiar with similar expressions dealing with polarized light. But something was bothering me.

If you had to apply the probability expression to derive the spin of the second particle, why was it not needed in the derivation of the spin probability of the first particle? I looked at all of the assumptions that had been made to generate the table, checked my math and so forth. Everything seemed reasonable.

Then I zeroed in on the assumption that if the spin were at all in the "Up" direction than it would show as "Up" and vice-versa. While it seemed reasonable, I realized that I had no basis for that assumption. So I proceeded to do a little more research.

That research led me back to the original Stern-Gerlach experiment with spin. Their experiment did prove conclusively that detection of spin was a quantized characteristic of particles. It did not, from what I have found so far, prove which spin directions would be quantized “Up” or “Down”. We just assumed that the crossover point was when the spin was more up then down. My conclusion at this point is that nature does not appear to work that way.

Let me describe, in more detail the Stern-Gerlach experiment.



Note: image taken from http://en.wikipedia.org/wiki/Stern-Gerlach_apparatus

In the Stern-Gerlach experiment, it was shown that the spin of a particle was either all up or all down. The classical model would have shown a range of up or down depending on the orientation of the spin relative to the magnets.

The assumption that was not proved by the experiment is that if the spin is at all in the up direction, it will result in an “up” result. It is probably safe to say that if the spin is at all up, the result of a measurement has a higher probability of being “up” rather than “down”.

How can we prove or disprove this idea? I would suggest running the Stern-Gerlach experiment with a spin filter we can rotate placed between the furnace and the inhomogeneous magnetic field. If, as we rotate the spin filter we see first one dot, then two dots, then the other dot, than back to two dots with their intensities varying sinusoidal, then we have pretty good evidence that the problem is as described above.

That same kind of misinterpretation applies to experiments run with polarization of photons.

I have not been able to get enough information on the Satigny-Jussy-Geneva tests over an 18 km range to see if it has the same problem. See:

http://www.physorg.com/news132830327.html

The sensibility test:

This brings us back to the pseudo-code mentioned earlier in this document.

If you remember, I used a detector function which would return +1 if the angle was at all in the same direction as the detector and –1 if not. When I replaced the detector function with a function that simply returned the cosine of the argument representing the portion of detected items, the result was exactly 0.5. This sounds like the classical physics result that would be expected without Bell's theorem and, for that matter, without quantum physics (except of course that the detector give quantized results).

Experimental Proof:

Aside from the sensibility check done with the pseudo-code, the following tests were conducted to verify the concept:

TBS

Conclusion:

Bell’s Inequality appears to be correct. None of the analyses have shown otherwise. However, the current experiments meant to prove Bell’s Inequality appear to have made a wrong assumption. The results of these experiments neither confirm nor deny Bell’s Inequality.