Assignment #2: Bell's Inequalities (due Feb. 22)

1. **(3 points)** The deterministic hidden variables theory of the correlated spin experiments discussed in class can be salvaged—even in the face of the observed statistics for the experiments in which $\theta_1 \neq \theta_2$—if we assume that the choice of magnet settings on the left and right, on any given run of the experiment, is *not independent* of the state of the particle pair. (This is the assumption that there is a "hidden conspiracy".) Show, in detail, why this is so.

In the experimental situation described in handout #2, it is possible to construct the particle generator in such a way (a way *different* from the way it is constructed in the experiments we discussed; a way such that particle pairs produced by this new generator will *not* produce the perfect correlations we examined), and to choose values **a** and **b** for θ_1 and values **c** and **d** for θ_2 in such a way, that the following facts obtain:

(i) When $\theta_1 = $ **b** and $\theta_2 = $ **d**, particles 1 and 2 *never* both go down.

(ii) When $\theta_1 = $ **a** and $\theta_2 = $ **d**, particles 1 and 2 *never* both go up.

(iii) When $\theta_1 = $ **b** and $\theta_2 = $ **c**, particles 1 and 2 *never* both go up.

2. **(2 points)** Assume that Einstein's assumption of locality is correct—that is, that the behavior of one particle in its experiment is unaffected by what is going on in the other experiment. Assume in addition that there is no "hidden conspiracy"—that is, that the choice of settings for θ_1 and θ_2 on any given run of the experiment is independent of the state of the particle pair. Show that it *follows* from these assumptions that a *partial* deterministic hidden variables theory must describe the behavior of the particles in these experiments. More specifically, show that it must be the case, on any given repetition of the experiment, that *either* the left-hand particle's behavior is fully determined (that is, it is fully determined, before that particle encounters its magnet, whether it will go up or down if its magnet is set to **a**, *and* whether it will go up or down if its magnet is set to **b**),

or the right-hand particle's behavior is fully determined. (Bear in mind that it might be the left-hand particle that is fully determined in one repetition, the right-hand particle in the next repetition, etc.) Show, in addition, that if the left-hand particle's behavior is fully determined, then the right-hand particle's behavior is at least *partially* determined, and vice versa. ("Partially determined" here means that the particle's behavior is predetermined for at least *one* choice of its magnet's setting.) Finally, construct a table that clearly displays all the possible properties that the two particles can have, consistent with facts (i) - (iii). (For "properties" here, we mean nothing very detailed. For example, the left-hand particle will have, on any given run of the experiment, one of the following three properties: (i) the property that it is certain to go up if its magnet is set to **a**; (ii) the property that it is certain to go down if its magnet is set to **a**; (iii) the property that it has some non-zero chance of going up, *and* some non-zero chance of going down, if its magnet is set to **a**.)

3. **(2 points)** In addition to facts (i) - (iii), the following fact *also* obtains:

(iv) When $\theta_1 = a$ and $\theta_2 = c$, particles 1 and 2 sometimes both go up.

Show that this additional fact guarantees that the assumptions of locality and no "hidden conspiracy" cannot both be correct.