Quantum Physics 2010/11

Tutorial Sheet 10: Bell's Theorem

1. Two photons travel in opposite directions toward two linear polarisers A and B at angles θ_A and θ_B to the z-axis. What is the probability that both pass through if they are:

   (a) Uncorrelated - produced by different sources.

   (b) Produced in an uncorrelated state polarised in the z-direction.

   (c) Produced in a correlated state with opposite polarisations from a spherically symmetric source.

   Two electrons travel in opposite directions and are deflected by two Stern Gerlach apparatuses, A and B at angles θ_A and θ_B to the z-axis. What is the probability that "spin up" is measured by both apparatus (i.e. one spin $\frac{1}{2}$ points along θ_A and the other along θ_B) if the electrons are:

   (d) Uncorrelated - produced by different sources.

   (e) Produced in a correlated state with opposite polarisations from a spherically symmetric source.

   Explain why (c) and (e) give different answers. Which cases would be different in the 'hidden variables' interpretation of quantum mechanics?

   What, in each case, are the average probabilities taken over all angles θ_A and θ_B?

2. At some stage, every physicist should read some classic literature. Here's your chance...

   Find copies of the three papers.

   A. Einstein, B. Podolsky, and N. Rosen, Can Quantum-Mechanical Description of Physical Reality Be Considered Complete? Phys. Rev. 47, 777 - 780 (1935)

   and

   J. S. Bell, On the Einstein Podolsky Rosen Paradox, Physics 1, 195 (1964)

   A. Aspect, J. Dalibard, and G. Roger: "Experimental test of Bell's inequalities using time-varying analyzers" Physical Review Letters 49 1804 (1982).

   and write a summary of the conclusions.