M520 Non-Relativistic Quantum Mechanics	Ninnat Dangniam

Homework Assignment 5

DUE: Wednesday 20 September 2023   30 points

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1. Quantum nonlocality without probabilities (10 points).

Consider the following state of three spin-1/2 systems:

$$|\psi\rangle = \frac{|+++\rangle - |---\rangle}{\sqrt{2}}.$$

This is, up to a sign flip, the *Greenberger-Horne-Zeilinger* (GHZ) state.

(a) Show that $|\psi\rangle$ is a $+1$ eigenstate of $X \otimes Y \otimes Y$, $Y \otimes X \otimes Y$, and $Y \otimes Y \otimes X$.

(b) Use the results of part **(a)** to argue that each spin-1/2 has well-defined values of X and Y. For spin j, denote these values by x_j and y_j. We say that these values are *elements of reality*. What does local realism, i.e., the assumption of realistic values that are undisturbed by measurements on other spins, predict for the product of the outcomes of measurements of X on each spin?

(c) What does quantum mechanics predict for the product of the outcomes of X measurements on each spin?

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2. (10 points). C-T F_{VI} 2.

3. (10 points). C-T F_{VI} 3.

The results of Problem 3 show, in particular, that the three components of the position operator $\hat{\mathbf{r}}$ and those of the momentum operator $\hat{\mathbf{p}}$ are *vector operators*, whereas $\hat{\mathbf{r}}^2$, $\hat{\mathbf{p}}^2$, and $\hat{\mathbf{r}} \cdot \hat{\mathbf{p}}$ are *scalar operators* with respect to rotations.