1 Expectation Values for a Particle on a Ring: Instructor's Guide

Expectation Values for a Particle on a Ring Handout

1.1 Introduction

It could be beneficial to see what students remember about expectation values by having asking them a Small White Board Question about the topic. Use their responses to drive an intro discussion about what expectation value is: not a measurement, but a weighted average.

1.2 Student Conversations

- **Operators vs Measurement:** Students commonly attempt to determine the values resulting from a quantum experiment by allowing the operator corresponding to the observable of interest to act on the initial state. Students who do this should be encouraged to consider the nature of this transformation (it's a vector, not a scalar) and to recognize that the transformation does not necessarily yield an eigenvector (the state of the system should be an eigenstate after the measurement).
- **Degeneracy:** Students may experience some difficulty due to the degeneracy of some states, in particular, that you have to include all the states that share that eigenvalue.

$$P_{E=\frac{m^2\hbar^2}{2I}} = |\langle m|\psi\rangle|^2 + |\langle -m|\psi\rangle|^2$$

- **Notation:** As with earlier activities, students are usually comfortable at this point with doing expectation values in bra-ket notation, but fewer are comfortable with using wavefunction notation. For groups that finish early, ask them to use the other method to compare.
- **Time Dependence:** Some students might wonder about the time-(in)dependence of their expectation values. This is a good opportunity to remind students of Time Dependence for a Quantum Particle on a Ring Part 1 where we discussed that quantities whose opperator commutes with the Hamiltonian will have time independent probabilities.

1.3 Wrap-up

This activity provides an opportunity to contrast two methods of finding expectation values.

- Carry out the explicit and messy differentiation and integration on the given state.
- Recast the initial state as a linear combination of eigenstates and carry out the much simpler calculations on these eigenstates.

Generally, students in the class will be mixed in the approach they choose. By emphasizing this when you wrapup this activity, students have the opportunity to sort out for themselves the benefits of each method. Remind them of Energy and Angular Momentum for a Quantum Particle on a Ring where

they made this sort of comparison explicitly.

Discuss some sense-making techniques for expectation value such as: units of the expectation value, what the expectation values tells you about the distribution of possible measurement values. Drawing a histogram of possible measurements vs probability might be a good way to illustrate these properties to students.

1.4 Extensions and Related Materials

This is a part of Quantum Ring Sequence of activities.