2015.16 PH2b – WINTER TERM

QUIZ 4

Your solutions are due on TUESDAY MARCH 01, 2016 at 11:00am, in the locked section boxes outside 201 E. Bridge. Late quizzes will not be accepted, except in very special circumstances.

The quiz is open book, open lecture, open section notes, open homework sets and solutions. Calculators may be used. Symbolic manipulators, other than your brain are not allowed. Please justify your answers and show all work.

TIME LIMIT: 120 MINUTES

IMPORTANT: Please write your name, your section number and your T.A’s name on the front of your solution sheet.

THERE WILL BE A QUIZ REVIEW ON SATURDAY FEBRUARY 27, 2016 AT 1:00PM IN 201 E. BRIDGE.
Physics 2B

Quiz 4

2016

Problem 1) (5 pts)

Consider a spin 1/2 particle in the state

\[ \chi = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 \\ i \end{pmatrix} \]  

(1)

a) [1.5pts] Compute \( \langle S_z \rangle \), \( \langle S_y \rangle \), \( \langle S_z \rangle \), and \( \langle S^2 \rangle \).

b) [1pt] Compute the expectation values of \( S_x S_y - S_y S_x \), \( S_+ \), and \( S_- \). Are these expectation values real? What does this imply about whether these operators are observables?

c) [1pt] Compute the expectation value of \( S_x S_y + S_y S_x \).

d) [1.5pt] Compute \( \langle S_x^{2n} \rangle \) and \( \langle S_y^{2n+1} \rangle \) where \( n \) is a positive integer.

Problem 2) (3pts)

a) [1pt] Explain why up to 8 electrons, but no more, can occupy the \( n = 2 \) atomic orbitals and up to 18 electrons, but no more, can occupy the \( n = 3 \) atomic orbitals.

b) [2pt] Imagine a different universe in which electrons have spin 3/2 rather than 1/2. Let’s consider how atomic structure would change. Specifically, how many electrons occupy the \( n = 2 \) and \( n = 3 \) orbitals? In this universe, what would be the atomic numbers \( Z \) of the two lightest “noble gases” (analogous to He and Ne in our universe).

Problem 3) (2 pts)

An electron is in the ground state of tritium (a Hydrogen isotope with 1 proton and 2 neutrons in the nucleus). A nuclear reaction changes the nucleus to \( ^3\text{He} \) (a Helium isotope with 2 protons and 1 neutron in the nucleus).

[2pt] What is the probability that the electron is measured to be in the ground state of the resultant \( ^3\text{He} \) atom?

\textbf{Hint 1}: Remember that a change in the charge of the nucleus alters the Coulombic potential that enters the Hamiltonian.

\textbf{Hint 2}: The nuclear reaction does not alter the wavefunction of the electron.