University of Louisville
College of Arts and Sciences

Department of Physics and Astronomy PhD Qualifying Examination (Part I)

Spring 2013

Paper D – Quantum Mechanics

Time allowed – 90 minutes

Instructions and Information:

- Answer both questions
- This is a closed book examination
- Start each question on a new sheet of paper – use only one side of each sheet
- Write your identification number on the upper right hand corner of each answer sheet
- You may use a non programmable calculator
- Partial credit will be awarded.
- Correct answers without adequate explanations will not receive full credit.
- Make sure your work is legible and clear
- The points assigned to each part of each question is clearly indicated

Quantum Mechanics Basic Level

The positron is the anti-matter partner of the electron (same mass, but opposite electric charge). An electron-positron pair can form a hydrogen-like system called positronium.

(a) Calculate the energy of the three lowest states of the positronium. (25)

(b) Determine the photon wavelength associated with a transition of the positronium system from n = 2 to n = 1. (10)

Supplemental information:

$$\frac{m_e e^4}{(4\pi\varepsilon_0)^2 2\hbar^2} = 13.6\ eV$$

where e is the magnitude of the electron charge, m_e is the electron mass, $\hbar$ is the reduced Planck constant, and ε_0 is the dielectric constant of vacuum.

Quantum Mechanics Intermediate Level

A particle in the one-dimensional infinite square well has as its initial wave function an even mixture of the first two stationary states: $\Psi(x,0) = A\left[\psi_1(x)+\psi_2(x)\right]$, where

$$\psi_n(x) = \begin{cases} \sqrt{\frac{2}{a}}\sin\left(\frac{n\pi x}{a}\right), & \text{if } 0 \le x \le a, \\ 0, & \text{otherwise} \end{cases}.$$

(a) Normalize $\Psi(x,0)$ and find A. (Note that $\{\psi_n(x)\}$ are orthonormal functions) (15)

(b) Find $\Psi(x,t)$ and $|\Psi(x,t)|^2$. Express the latter as a sinusoidal function of time, in terms of $\omega \equiv \pi^2\hbar/2ma^2$. (20)

(c) If you measured the energy of this particle, what values might you get, and what is the probability of getting each of them? (15)

(d) Find the expectation value of $\hat{H}$. How does it compare with E_1 and E_2? (15)