QUANTUM MECHANICS I

PHYS 516

Problem Set # 1
Distributed: Jan. 9, 2015
Due: January 19, 2015

1. Scaling: Bohr computed the energy level spectrum of the hydrogen atom using the Old Quantum Theory, Heisenberg did the same using Matrix Mechanics, and so did Schrödinger using Wave Mechanics. They all derived

$$E_N = \frac{E_g}{N^2} \qquad E_g = -\frac{1}{2}mc^2\alpha^2/N^2 \qquad R_N = Na_B \quad a_B = \hbar^2/me^2 \tag{1}$$

Here $N = 1, 2, 3, ...$ is the principal quantum number, $-e$ is the charge on the electron, m is the mass of the electron (actually electron-proton reduced mass), $\alpha = e^2/\hbar c = 1/137.036...$ is the fine structure constant, and a_B is the Bohr radius. $E_1 = -13.6eV$ and $a_B = 0.529 \times 10^{-8}cm$.

For each of these pairs compute the binding energy and the size (diameter):

System	Energy	Size
hydrogen atom: p^+e^- (nonrelativistic)	13.6 eV	1.058 Å(diam.)
$\mathrm{He}^{\mathrm{II}}$:		
mu-mesic atom: $p^+\mu^-$		
pi-mesic atom: $p^+\pi^-$		
positronium: e^+e^-		
muonium: $\mu^+\mu^-$		
pionium: $\pi^+\pi^-$		
Si exciton: $\epsilon = 11.9, m_e = 0.8m, m_h = 0.4m$		
GaAs exciton: $\epsilon = 12.5, m_e = 0.07m, m_h = 0.4m$		

El^{I} is neutral Element, and El^{n+1} is Element without n of its electrons. For excitons the electron (m_e) and hole (m_h) effective masses are given as multiples of the free electron mass. Recall that the mass m used in expressions for the hydrogen atom properties is the proton-electron reduced mass.

2. Polarization: A light beam is sent through a polarizer that allows vertically polarized light through.

a. What are the amplitude and intensity of light transmitted through a second polarizer making an angle of $\pi/2$ radians with the first?

b. Two polarizers are placed behind the first, each rotated through an angle $(\pi/2)/2$ with respect to the previous. What are the amplitude and intensity of the transmitted light?

c. Now n polarizers are placed behind the first, each rotated by $(\pi/2)/n$ with respect to the previous. What are the amplitude and intensity of the transmitted light?

d. In the limit $n \to \infty$ what are the amplitude and intensity of the transmitted light?

3. Losses: Assume each polarizer absorbs 10% of the incident energy. What is the maximum efficiency that can be obtained in rotating the plane of polarization of a light ray from vertical to horizontal?