Examination II-ver A

Name: ____________________________

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Physics 222
Spring 2014, TAMUQ
Hans A. Schuessler

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Time: 50 min

Show all of your work on work out problems

Part I: Multiple Choice Questions

1. Who did first accurately measure the value for the charge of the electron?

   (5pts)
   a. Röntgen
   b. Planck
   c. Millikan
   d. Thomson
   e. Einstein

2. The Rydberg equation is used to:

   (5 pts)
   a. determine the ratio of the electron charge to its mass
   b. measure the mass of the hydrogen atom
   c. calculate the wavelengths of different transitions in energy level of electrons in helium
   d. Calculate the diffraction pattern from Bragg planes in a crystal.
   e. calculate the wavelengths of different spectral lines of hydrogen

3. How did Planck modify the classical theory of blackbody radiation to correctly determine his radiation law?

   (5 pts)
   a. He found that the blackbody model was incorrect for purposes of theory
   b. He assumed light was absorbed and emitted in quanta
   c. He accepted the Stefan-Boltzmann Law
   d. He realized that the charge of the electron was not quantized
   e. He proved the necessity of relativistic considerations.
4. Consider the photoelectric effect when one increases only the frequency of the incoming light onto the emitter, one measures
   a. An increase in the necessary stopping voltage
   b. An increased current
   c. A decrease in the necessary stopping voltage
   d. No change in either current or stopping voltage
   e. Either a or c. You cannot determine which from the information given.

5. Which of the following statements is correct about the experiment that first measured the charge of the electron?
   a. The oil drop is suspended because there are no forces acting on the drop
   b. The important result was that Coulomb attraction made all the oil drop the same mass, regardless of type of oil
   c. The valve for electron charge had an experimental error of about 35%
   d. The mass of the drop was determined by measuring its terminal velocity
   e. Light hitting the oil drops manipulated their movement in a way to create an interference pattern.

6. How did Thomson measure the charge to mass ratio of the electron?
   a. He shot helium nuclei into gold foil to measure the nuclei scattering against electrons within.
   b. He suspended a drop of oil between electrodes to measure the electric field from the electrons.
   c. He measured very precisely a known quality of hydrogen atoms and calculated the reduced mass ration within each atom.
   d. He passed cathode rays through a magnetic field and measured the deflection

7. The de Broglie wavelength of which of the following objects would be largest if the objects had the same velocity?
   a. Tennis ball
   b. Electron
   c. Proton
   d. Hydrogen atom
   e. All the same wavelength
8. Which of the following statements is most correct about the uncertainty principle?
   (5 pts)
   a. An electron with some momentum can be trapped into an arbitrarily small box.
   b. It is impossible to know exactly both the position and the momentum of a particle simultaneously.
   c. Our instruments will eventually be able to measure more precisely than the principle presently allows.
   d. On large length scales, the uncertainty principle dominates our understanding of the physical world.
   e. A particle limited in space can occupy any energy.

9. Which of the following is an important difference between the infinite square-well potential and the finite square-well potential?
   (5 pts)
   a. The number of energy levels is limited in the infinite square-well potential but not limited in the finite square-well potential.
   b. The infinite square-well potential utilizes Schrödinger's equation to describe particle motion while the finite square-well potential does not.
   c. Particles can exist in classically forbidden regions outside the finite square-well potential.
   d. The energy levels are quantized only in the finite square-well potential.
   e. Only the energy levels in the finite square-well potential depend on Planck's constant.

10. At what wavelength is the radiation emitted by a human body at its maximum? Assume a temperature of 37°C.
    (5 pts)
    a. 1.16μm
    b. 503nm
    c. 4.15μm
    d. 850nm
    e. 9.35μm

11. Consider building a scale model of the hydrogen atom using a Bohr's theory. You start with the proton and give it a diameter of 1cm in your setup. What is the diameter of the orbit of the electron if it is to be depicted as being in the first excited state?
    (5 pts)
    a. 500m
    b. 2000m
    c. 1.3km
    d. 6km
    e. 30m
12. Consider the Franck-Hertz experiment and select the correct statement.
(5 pts)
   a. The electron makes an inelastic collision and excites the Hg atom to the first excited state.
   b. The collector current versus stopping voltage graph has maxima for each energy value of the Hg atom.
   c. The collector current versus stopping voltage graph has minima for each energy value of the Hg atom.
   d. An electron energy of 4.88 eV is needed before this electron can lose its energy in an elastic collision with the Hg atom.

13. Compare the finite and infinite square well potentials and choose the correct statements.
(5 pts)
   a. There are an infinite number of bound energy states for the finite potential.
   b. There are bound states which fulfill the condition $E > V_0$.
   c. There are a finite number of bound energy states for the finite potential.
   d. The wave lengths are shorter for the finite square well.

14. Which of the following states of the hydrogen atom is allowed?
(5 pts)
   a. $n = 6, l = 5, m_l = -5$
   b. $n = 2, l = 2, m_l = 0$
   c. $n = 5, l = 2, m_l = 3$
   d. $n = 1, l = 2, m_l = 1$
Part II: Short problems

15. Find the energies of the first, second, third and fifth levels for the three
(15 pts) dimensional cubical box. Which energy levels are degenerate? How many fold
degenerate is each level? Use \( E_0 \) express your answer!

\[
E_0 = \frac{n^2 \hbar^2}{2mL^2}
\]

\[
\begin{align*}
E_1 &= (1^2 + 1^2 + 1^2) E_0 = 3E_0 \quad \text{(not degenerate) (1 fold)} \\
E_2 &= (2^2 + 1^2 + 1^2) E_0 = 6E_0 \quad \text{(3 fold degenerate) (2 fold)} \\
E_3 &= (2^2 + 2^2 + 1^2) E_0 = 5E_0 \quad \text{(3 fold degenerate) (3 fold)} \\
E_5 &= (2^2 + 2^2 + 2^2) E_0 = 12E_0 \quad \text{(not degenerate) (1 fold)}
\end{align*}
\]
16. Determine the expectation value for $\rho$ of a particle in an infinite square well for the first excited state. Use: $\psi(x) = \sqrt{\frac{2}{L}} \sin \frac{2\pi n x}{L}$.

For $n = 2$, namely the first excited state:

$\psi_2(x) = \sqrt{\frac{2}{L}} \sin \frac{4\pi x}{L}$

Expectation value for $n = 2$: use $\hat{\rho} = -i \hbar \frac{d}{dx}$

$\langle \hat{\rho} \rangle_{n=2} = -\hbar \frac{d}{dx} \left[ \sqrt{\frac{2}{L}} \sin \frac{4\pi x}{L} \right] \left[ \sin \frac{4\pi x}{L} \right] dx$

$= - \frac{4\pi \hbar}{L} \int_0^L \sin \left( \frac{4\pi x}{L} \right) \cos \left( \frac{4\pi x}{L} \right) dx = 0$

$= -\frac{1}{\hbar} \left[ \cos^2 \frac{4\pi x}{L} \right]_0^L = -\frac{1}{\hbar} \left[ 1 + \frac{1}{2} \right] = 0$

$\langle \rho \rangle = \frac{2\bar{u} x}{L}$

$x = 0 \rightarrow \rho = 0$

$x = L \rightarrow x = 2\pi$

$\int \cos x \cdot \sin x \, dx = \int k \, du = \frac{u^2}{2}$

$u = \cos x$

$du = -\sin x \, dx$