國立清華大學命題紙

九十二學年度 光電工程研究所 系（所） ________ 組碩士班研究生招生考試

科目 近代物理 科號 2504 共 三 頁第 一 頁 *請在試卷【答案卷】內作答

1. Suppose we want to "see" the electron orbit of a hydrogen atom (as proposed by Bohr) with photon of sufficient small wavelength, $\lambda = 0.1$ Å
   (a) What is the energy of such photon? (5%)
   (b) In a Compton head-on collision, how much energy will such a photon be transferred to an electron? (5%)
   (c) How does this gained energy compared to the ionization energy (13.6 eV) of the hydrogen atom? Does the ideal of "seeing" electron orbit make sense in this way? (5%)

   (Use $h = 4 \times 10^{-15}$ eV·s, $m_e = 9 \times 10^{-31}$ kg $= 5 \times 10^5$ eV/c^2, $c = 3 \times 10^8$ m/s $\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$)

2. The total energy of a harmonic oscillator can be expressed as $E = \frac{p^2}{2m} + \frac{1}{2}kx^2$.

   In classical physics, the minimum energy of a harmonic oscillator is $E = 0$. But things are different in quantum world due to the uncertainty principle.
   (a) By using uncertainty relation, write down the expression for the estimated total energy in terms of displacement x only. (5%)
   (b) By minimizing the total energy with respect to x^2, find the value of x^2. (5%)
   (c) Calculate the minimized energy E_{min} in part (b) and show $E_{\min} = \frac{1}{2}hf$

   where $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$. (5%)

3. Please describe a "thought" experiment where photons show the so-called wave-particle duality. (15%)

4. Consider a finite potential well

   $V(x) = 0, \quad -L < x < L$

   $V(x) = V_0, \quad |x| > L$

   Draw **qualitatively** three wave functions with the energies E_1, E_2, and E_3, respectively. These energies satisfy the following properties

   i) $E_1 < V_0$ and E_1 is the ground state, (8%)

   ii) $E_2 > V_0$, (5%)

   iii) $E_3 >> E_2 > V_0$ (7%)

   Note that the drawing must clearly show the wave function both **inside and outside** the well, and the **qualitative difference** between the three cases.

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5-11 多選題（正確答案可能不只一個，全部選對才有分）

5. Two copper conducting wires are separated by an insulating oxide layer (CuO). Under certain circumstances at room temperature, there is still current flowing. This phenomenon could be caused by (a) superconducting effect in CuO (b) spin-orbit interaction of the conducting electrons in CuO (c) Compton effect in CuO (d) electron tunneling in CuO (e) dielectric breakdown in CuO (f) none of the above. (5%)
6. For hydrogen atom at ground state, magnitude of the total angular momentum of the orbiting electron is (a) 0 if the spin is neglected (b) $\sqrt{2}\hbar$ because orbital quantum number $\ell=1$ (c) $\pm\hbar$ because of the uncertainty principle (d) $\sqrt{3}/2\hbar$ (e) $1/2\hbar$ (f) none of the above. $\hbar$ is the Planck constant (5%)
7. Bohr radius is (a) the radius of ground state electron orbit in Bohr's model (b) the position of the maximum radial probability distribution of the ground state electron in hydrogen atom (c) the averaged distance from the nucleus of the ground state electron in hydrogen atom (d) radius of the electron in hydrogen atom when the quantum number is equal to 1 in Bohr's model (e) the radius of the electron orbit for the case when quantum number is very large in Bohr's model (f) none of the above. (5%)
8. The first experiment for discovering electron spin was performed by Stern-Gerlach on silver atom. In the Stern-Gerlach type of experiment on hydrogen atom (a) the ground state hydrogen beam will split into three after it passes the magnet (b) if we neglect the spin effect, we should expect even number of beam pass through (c) a nonuniform magnetic field is required for the experiment (d) the outcome has the same origin as the anomalous Zeeman effect (e) we can find that the electron has intrinsic angular momentum with quantum number ±1 (f) none of the above. (5%)
9. Fermi-Dirac distribution function is valid for (a) system of free electrons (b) systems of half integral spin particles (c) electrons in periodic potential (d) electrons in insulator (e) electrons in conductor (f) none of the above. (5%)
10. Heisenberg's uncertainty principle tells us that (a) experimental errors from instruments on position and momentum measurement are inevitable(不可避免的)(b) it is impossible to precisely measure the position and momentum of a particle at different time (c) it is possible to precisely measure the position and momentum of a particle simultaneously (d) the position and momentum of a particle can be measured precisely and simultaneously under certain circumstances (e) if you measure the position of a particle then you can not measure the momentum of the same particle (f) none of the above. (5%)

11. The tunneling probability for a particle is (a) approximately one when the particle mass is very large (b) approximately one when the particle energy is very small (c) independent of the barrier width (d) independent of the barrier height (e) independent of the particle mass and energy (f) none of the above. (5%)