國立清華大學 106 學年度碩士班考試入學試題

系所班組別：核子工程與科學研究所甲組 (0528)

考試科目（代碼）：近代物理 (2803)

Useful constants: Coulomb constant $k = 8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}$, $c = 3.00\times10^{8}\ \mathrm{m/s}$, $h = 6.63\times10^{-34}\ \mathrm{J\cdot s}$, $e = 1.60\times10^{-19}\ \mathrm{C}$, $\mu_B = 9.274\times10^{-24}\ \mathrm{J/T}$, $m_e = 9.11\times10^{-31}\ \mathrm{kg}$

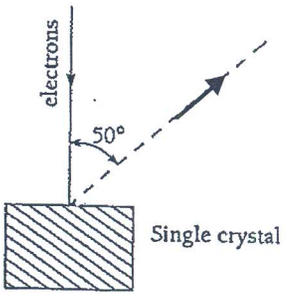
1. (10%) A space ship leaves earth at a speed of 0.8 c relative to the earth. From earth, pulsed laser signals are sent to the spaceship at the inteval of 1 year. What is the inteval of receiving these pulsed signals on the spaceship?

2. (10%) A neutral pion traveling along the X-axis decays into two photons with one photon moving exactly in forward direction and the other photon exactly backward. The first photon (moving in forward direction) has three times the energy of the second photon. Find the speed of the original pion. (The rest mass of pion is 150 MeV/c^2)

3. (10%) Estimate the approximate radius of the $n=1$ orbit of the innermost electron in the lead atom. Show the derivations. (the atomic number of lead is 82)

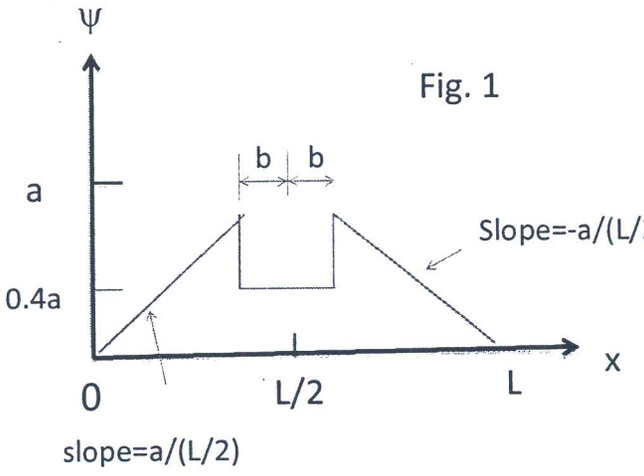
4. (10%) Write down the equations to calculate the average energy $\overline{E}$ emitted by the oscillator of a black body radiator both by Rayleigh-Jeans and by Planck, respectively. (just write the equations for calculating the $\overline{E}$, do not need to derive the results of $\overline{E}$).

5. (10%) A beam of 50 keV electrons is directed at a crystal and the diffracted electrons are found at an angle of 50° relative to the original beam. What is the spacing of the atomic planes of the crystal? A relativistic calculation is required for calculating λ.



6. (5%) In one dimension, a wave-like particle stays inside a box of length of L. The wavefunction, Ψ, can be seen in Fig. 1. What is the expectation value <x> of the position of a particle in the box ? _____

Fig. 1



7. (5%)In the quantum mechanics:
   甲、What is associated operator of position x, _____.
   乙、What is associated operator of momentum p, _____ .
   丙、What is associated operator of potential energy U(x), _____
   丁、What is associated operator of kinetics energy K, _____
   戊、What is associated operator of total energy E, _____

8. (5%) In one dimension, an eigenfunction of the operator d^2/dx^2 is $\Psi = e^{-x}$. Find the corresponding eigenvalue. _____

9. (5%) What is the meaning of the degenercy? Please interpret it from the view point of a particle wavefunction inside the cubic box and rectangular box.

10. In the radiation emission of an excited hydrogen atom, we observed that the most probable emission of photon is from 2p state to 1s and then 3p state to 1s state. However, we cannot observe the 2s to 1s state and 3p to 2p states. Please explain why is that? _____ (2%). Please also explain why the intensity ratio of emission photons from $P_{3/2}$ to $S_{1/2}$ and $P_{1/2}$ to $S_{1/2}$ orbits is 2:1 not 3:1? _____(3%)

11. (4%) Please write down the full names of four quantum numbers (n, l, m_l, m_s) IN ENGLISH (There will no score if you write in Chinese)_____

12. If we have a wavefunction of $\Psi(x,t)$ extended only inside a cubic box with each side of L, please write down the normalization condition. _____ (3%). If this wavefunction represents a particle, where is the expectation position of this particle? _____ (3%)

13. (5%) Electron spin m_s has only two states. Which experiment is the first discovery of this phenomena: _____.

14. (5%) In a STM experiment, we applied a constant potential, V = 10 V, between the tip and the conducting substrate. The tunneling current is exponentially increased as the distance between the tip and substrate decrease linearly. Now, I knew if the distance between the tip and substrate decrease by 0.02 nm, the tunneling current increase 2 times. When I move the tip away from the surface, I found the tunneling current was reduced nine times. Please tell me what is the distance between the surface and tip of the STM?

15. Answer the following questions:
   (1) (1%)In the Larmor precession of an electron under magnetic field, if I increase the magnetic field twice, how many times will the Larmor frequency changed?__
   (2) Please write the magnetic moment _____ of an orbiting charge in terms of q (charge), m (mass) and L (angular moment perpendicular to the orbit plane) (1%)
   (3) Please write down the electronic configuration of Zn and Zn^{2+} (1%) (Zinc atomic number 30)
   (4) Give the spectroscopic notation for the n=6, l=4, j=9/2. (1%)
   (5) The L X-ray is emitted in the transition from excited shell to ground shell of an atom. Please tell me which excited shell to which ground shell. Write down the names of the shells. (1%)