國 立 清 華 大 學 命 題 紙

95學年度 工程與系統科學 系（所）丙、戊 組碩士班入學考試

科目 近代物理 科目代碼 3504 3603 共 2 頁第 1 頁 *請在【答案卷卡】內作答

Useful constants: $c = 3.00\times10^{8}$ m/s, $k_B = 1.38\times10^{-23}$ J/K, $h = 6.63\times10^{-34}$ J·s,
$e = 1.60\times10^{-19}$ C, $m_e = 9.11\times10^{-31}$ Kg.

1. (20%) A photon of energy 1.92 MeV undergoes pair production in the vicinity of a lead nucleus. The created particles (one electron and one positron) have the same speed, and both travel in the direction of the original photon. **Calculate the recoil momentum of the lead nucleus.** The mass of the lead nucleus is $M = 3.44\times10^{-25}$ Kg.
(Hint: Because the lead nucleus is so massive, its kinetic energy can be neglected in the calculation.)

2. (15%) About the photoelectric effect.
   (a) Draw the experimental setup for measuring the photoelectric effect. Describe the photoelectric effect and explain how the experiment is conducted.
   (b) What is the maximum energy of the emitted photoelectron and how you measure it experimentally?
   (c) How to determine the work function of the metallic emitter from the experiment?
   (d) What will you find when you shine the metallic emitter with lights of different intensity but same frequency? Also, what will you find when you shine the metallic emitter with lights of different frequency but same intensity?

3. (15%)
   (a) Please give two experimental examples that show the particle properties of waves. Describe briefly about these experiments.
   (b) Please give two experimental examples that show the wave properties of particles. Describe briefly about these experiments.

4. (15%) Two possible eigenfunctions for a particle moving freely in a region of length a, but **strictly confined to that region, are shown in Fig. 1.** When the particle is in the state corresponding to the eigenfunction ψ_I, its total energy is 4 eV.
   (a) What is its total energy in the state corresponding to ψ_{II}?
   (b) What is the lowest possible total energy for the particle in this system?

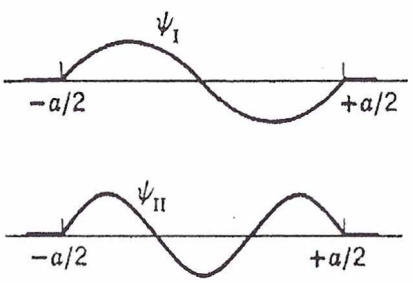

Fig. 1

(continued to the next page)

5. (15%) The restoring force constant C for the vibrations of the interatomic spacing of a typical diatomic molecule is about 10^3 joules/m^2.
   (a) Estimate the zero-point energy of the molecular vibrations. The mass of the molecule is 4.1×10^{-26} Kg.
   (b) What is the energy difference between the ground state and the first excited state.
   (c) Determine the frequency of the photon emitted when the molecule makes a transition from the first excited state to the ground state.

6. (20%) The electron in a hydrogen atom occupies the combined spin and position state

$$R_{21}(r)\left[\sqrt{\frac{1}{3}}\,Y_1^0(\theta,\phi)\,\chi_+ - \sqrt{\frac{2}{3}}\,Y_1^1(\theta,\phi)\,\chi_-\right],$$

where χ_+ means spin up and χ_- means spin down.

(a) If you measure the orbital angular momentum squared (L^2), what values might you get, and what is the probability of each?
(b) Same for L_z.
(c) Same for the spin angular momentum square (S^2).
(d) Same for S_z.
(e) Let $\vec{J}\equiv\vec{L}+\vec{S}$ be the total angular momentum. If you measure J^2, what value might you get?
(f) Same for J_z.