

國 立 清 華 大 學 命 題 紙

98 學年度 工程與系統科學系丙組、核子工程與科學研究所甲組、先進光源科技碩士學位學程工程與系統科學組碩士班入學考試

科目 近代物理 科目代碼 2803、2903、3002 共 1 頁第 1 頁 *請在【答案卷卡】內作答

Useful constants: $c = 3.00 \times 10^8$ m/s, $k_B = 1.38 \times 10^{-23}$ J/K, $h = 6.63 \times 10^{-34}$ J·s, $e = 1.60 \times 10^{-19}$ C,
 $m_e = 9.11 \times 10^{-31}$ Kg, $\mu_B = 9.274 \times 10^{-24}$ J/T, $R = 1.097 \times 10^7$ m⁻¹.

1. (14%) (a) In a particular experiment, α particles from a radioactive source are scattered at $\theta = 10^\circ$ from a gold foil and 170,000 particles are counted each minute at the detector. If everything is kept the same except that the detector is moved to observe particles scattered at 90° , how many particles will be counted per minute?
(b) What energy α particle would be needed to just reach the surface of an aluminum nucleus if its radius is 4 fm?
2. (14%) Gamma rays emitted by radioactive nuclei also exhibit measurable Compton scattering. Suppose a 0.511-MeV photon from a positron-electron annihilation scatters at 110° from a free electron.
(a) What are the energies of the scattered photon and the recoiling electron?
(b) What is the direction of the recoiling electron relative to the initial direction of the 0.511-MeV photon?
3. (14%) The wave function for a free electron is given by $\psi(x) = A \sin(2.5 \times 10^{10} x)$ where x is in meters.
(a) Compute the electron's momentum, energy, and de Broglie wavelength.
(b) What is the expectation value of the electron's momentum?
4. (14%) (a) A hydrogen atom electron is in the $5f$ state. Find the energy (E), the magnitude of the orbital angular momentum (\bar{L}), and the possible values of L_z of the electron.
(b) How many lines would be expected on the screen of a Stern-Gerlach experiment if we use a beam of potassium ($Z=19$) atoms? What if we use a beam of calcium ($Z=20$) atoms? Explain.
5. (14%) (a) Given that the ionization energy of the potassium atom is 4.3 eV, find the effective charge seen by the outer electron.
(b) The wavelength of the K_α X-ray line for an element is measured to be 0.179 nm. What is the element?
6. (15%) A hydrogen atom in the ground state is placed in a uniform magnetic field of strength $B_z = 0.5$ T.
(a) Compute the energy splitting of the spin states.
(b) Which state has the higher energy?
(c) In order to excite the atom from the lower to the higher energy state with a photon, what frequency must the photon have?
7. (15%) Muons are unstable elementary particles that have a charge equal to that of an electron and a mass 207 times that of the electron. It is known that the lifetime of muons at rest is $2.2 \mu\text{s}$.
(a) Estimate the uncertainty of muon's rest energy.
(b) If the lifetime of some fast moving muons were measured to be $63.5 \mu\text{s}$, find the speed of these muons.
(c) Find the momentum of the fast moving muons in (b).