八十四學年度 生命科學 所 乙 組碩士班研究生入學考試

科目 近代物理 科號 1012 共 2 頁第 1 頁 *請在試卷【答案卷】內作答

(I) (30 points) Consider the relativistic collision process, $e^-(\vec{p}_1) + e^+(\vec{p}_2) \rightarrow \Psi \rightarrow \gamma_1(\vec{q}_1) + \gamma_2(\vec{q}_2)$, where an electron with momentum $\vec{p}_1$ collide with a positron with momentum $\vec{p}_2$ and create a particle, Ψ. The particle Ψ then decays into two photons (γ-rays) of momenta $\vec{q}_1$ and $\vec{q}_2$. Given the electron mass to be m_e and $\vec{p}_1 = (0, 0, p_1), \vec{p}_2 = (0, 0, p_2), \vec{q}_1 = (0, q\sin\theta, q\cos\theta)$ in the Lab. frame,
(a)What is the momentum $\vec{q}_2$?
(b)What are the energies of e^-, e^+, γ_1 and γ_2?
(c)What is the mass of the particle Ψ?
(d)What are the energies and momenta of e^- and e^+ in the center of mass frame?
(e)What are the energies and momenta of γ_1 and γ_2 in the center of mass frame?
(f)What are the wavelengths of γ_1 in the Lab frame and in the center of mass frame?

(2)(26 points) Given a spin 1/2 particle and a spin 1 particle with spins, $\vec{S}_1$ and $\vec{S}_2$, respectively. If the energy of the quantun mechanical system is $E = f\vec{S}_1 \cdot \vec{S}_2$, and ignoring all the other dynamical variables,
(a)how many possible quantum states are there for the system?
(b)What are the possible energy eigenvalues of the system?
(c)What is the degeneracy of each of the energy eigenvalues?

(3)(26 points) Consider an ensemble of spin 1/2 particles in a magnetic field B. Ignoring the orbital angular momentum, the Zeeman effect can be expressed as $\Delta E = -g\vec{S} \cdot \vec{B}$ where g is approximately a positive constant. Ignoring all the other dynamical variables,
(a)what are the energy eigenvalues of the particle in the magnetic field?
(b)At temperature T, what is the probability of finding a particle in the higher energy excited state?
(c)What is the temperature at which the probability of finding the particle in the excited state is the same as the probability of finding it in the ground state?

(4)Answer the following questions:(2 point each)

(a)What is the spin of a quark?

(b)How many quarks are in a proton?

(c)What is the mass of the neutrino from the beta decay?(in eV)

(d)What is the temperature of the Universe?(in Kelvin)

(e)What is the rough size of a hydrogen atom?(in cm)

(f)What is the rough size of a hydrogen nucleus?(in cm)

(g)What is roughly the binding energy of hydrogen atom?(in eV)

(h)What is the rough binding energy per nucleon for a typical long-lived nuclei?(in eV)

(i)At what atomic number, A, the above number reaches the maximum? (This number plays an important for the burning of a star).