Physics 7C Section 1
Spring 2006
Midterm 2. April 3, 2006
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Name:____________________ SID:____________________

Choose four out of the five problems proposed, the test duration is 120 minutes.

1. A collimated beam of 5.9 keV X-ray photons emitted by a ^{55}Fe radioactive source is sent on the face of a diamond crystal. Assume that the C atoms are arranged in the diamond crystal according to a cubic array, with an inter-atom spacing of 1.06 Angstrom.
i) Find the values of the angle between the incoming and the diffracted photon beam that give the first three maxima in the measured reflected intensity,
ii) Describe the result of the same experiment performed using a 400 nm laser beam.

2. Show that $\sum_i \Delta x_i^2 - c^2\Delta t^2 = 0$, where the index i runs over the three space coordinates, is invariant under transformations of the kind $x_i' = \gamma(x_i - v_i t)$, $x_i = \gamma(x_i' + v_i t')$, $t' \neq t$ where (x, t) and (x', t') denote two inertial frames moving at relative speed v. Use this invariance to derive the expression of γ.

3. A neutral kaon K^0, with mass $m_{K^0} = 494$ MeV/c^2 and energy $E_{K^0} = 10000$ MeV, decays into two neutral pions π^0, each with mass $m_{\pi^0} = 140$ MeV/c^2 according to the process $K^0 \to \pi^0\pi^0$:
i) Determine the opening angle of the two neutral pions $\theta_{\pi\pi}$ measured in the lab frame and the energy of each of the pions both in the K^0 rest frame and in the lab frame;
ii) An experiment produces a flux of monoergetic K^0 particles, knowing that the lifetime τ_0 of a K^0 meson at rest is 0.9×10^{-10} s and that the kaon flux is reduced according to the exponential law $I(t) = I(0)e^{-t/\tau}$, find the fraction $I(t)/I(0)$ of the original flux that will be measured, in the lab, 1 meter away from the kaon production point. monoergetic → monoenergetic

4. Very energetic protons ($m_p = 938$ MeV/c^2) collide with cosmic microwave background (CMB) photons where they lose energy by inducing the reaction $p\gamma \to \Delta \to p\pi^0$. This phenomenon suggests an absolute upper limit for the energy of cosmic ray protons, known as the GZK effect. Find the proton energy threshold E_p for this reaction, knowing that the mass of the Δ particle is 1232 MeV/c^2 and that the typical energy of a CMB photon is 2.35×10^{-10} MeV (assume head-on $p\gamma$ collisions).

5. Two photons of equal energy E_γ collide to produce an electron-positron pair $\gamma\gamma \to e^+e^-$ ($m_e = 0.511$ MeV/c^2):
i) Determine the minimum energy E_γ needed for this process to occur when the angle between the two photons is $\pi/2$ and π;
ii) a magnetic field $B = 3$ Tesla is established, with B parallel to the direction of the photons which are colliding head-on, determine the largest radius of curvature of the electrons emitted when E_γ=2000 MeV.